FINAL REPORT ON THE SURFICIAL MAPPING FOR THE PENOBSCOT BAY PROJECT

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Introduction

To characterize the ecosystem of Penobscot Bay the seafloor of the bay was mapped with side scanning sonar. About 120 km2 of new imagery of the bottom were gathered and compiled with earlier-gathered bathymetry, seismic reflection data and bottom samples. Maps of surficial sediment, bathymetry, physiography were produced along with mapped features like buoys, LORAN time-delay lines, cable crossings, and disposal sites. Trackline maps and bottom sample locations were also produced (Kelley, Kelley and Dickson, 1997a, b, c, d).

Procedures for Seafloor Mapping

Bottom Samples

In 1989, 169 bottom sample stations were occupied, in Penobscot Bay. Two attempts were made at each station where the sampler initially returned empty, after which the site was considered a rock bottom.

The bottom sampler used was a Smith-McIntyre stainless steel device that nominally collected up to 0.25 m3 of sediment. In mud, the sampler did gather 0.25 m3 of sediment, usually with the surface completely undisturbed. When the sampler was used over a sandy bottom it usually returned an undisturbed sample, unless a large shell blocked its jaws, permitting material to wash out. Over a gravel seafloor it was common for large clasts to prevent closure of the sampler's jaws, resulting in loss of some or all sediment. In those situations, up to two additional attempts were made to obtain a sample before abandoning the station. At stations where no sample could be collected, a hard bottom was inferred and rock was mapped.

Following collection, samples were frozen in coolers until they could be stored in a freezer in the sedimentology laboratory at the University of Maine. Samples were analyzed for grain size by standard laboratory techniques, with pipette methods to evaluate the percent of sand, silt and clay (Folk, 1984), a settling tube to evaluate sand size distribution (settling velocity), and a micromeritics sedigraph to measure the settling velocity of mud-size material (< 62 microns).

Side-Scan Sonar Profiles

Analogue side-scan sonar records were gathered (Figure 1)(Kelley et al., 1997a) with an EG&G Model 260 slant-range corrected device operating with a Model 272-T towfish at a nominal frequency of 105 kHz. The device was most often run at a 100 m range (200 m wide swath beneath the research vessel), although ranges from 25 m to 300 m were occasionally employed (swaths from 50 m to 600 m, respectively, beneath the boat).
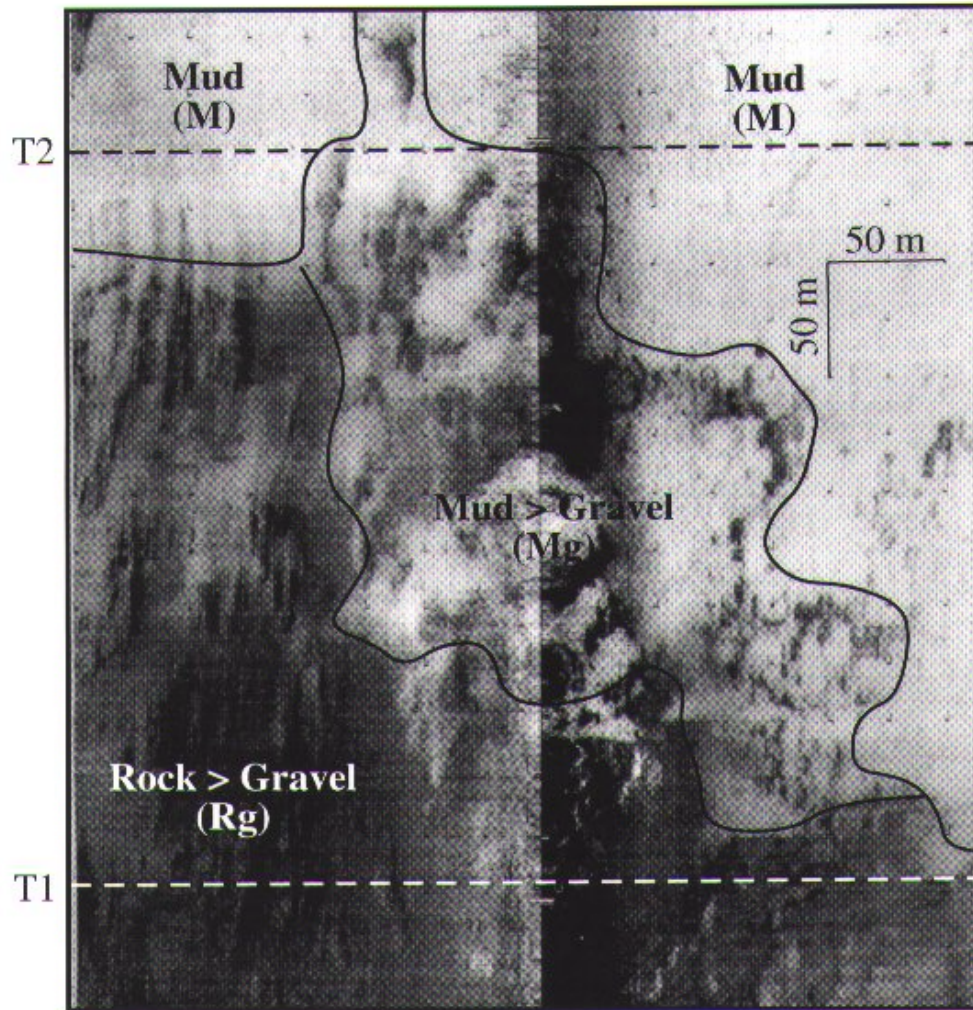
Figure 1. Side scan sonar line from Penobscot Bay. Composite units typical of those in the bay are shown. T1 refers to a time event with a navigation fix of 44 degrees 10. 452 minutes north and 68 degrees 43.504 minutes west. T2 refers to a time event with a navigation fix of 44 degrees 10.639 minutes north and 68 degrees 43.488 minutes west.

Interpretation of the side-scan sonar records was aided by ground-truth information from the 169 bottom samples collected earlier (Kelley and Belknap, 1989). Although objects as small as lobster traps and current ripples were visible at the 100 m range, it was not possible to make detailed textural distinctions using acoustic imagery alone or to directly compare acoustic images with samples that were analyzed for grain-size distribution. Thus, sandy mud and muddy sand, which are textural categories that can readily be distinguished with particle size analyses, are essentially identical in acoustic images. Where sand gradually mixes with mud, a contact was drawn in the midpoint between known occurances of sand and mud. Similarly, where grain-size data were lacking, rippled seabeds were called gravel, even though sand is commonly a minor component of the bedforms.

The heterogeneity of the seabed at all scales precluded mapping all features observed in the side-scan sonar records. To be visible on a map, a feature must be at least 1 mm2. This means that on a 1:100,000 scale map, the smallest mappable unit on the seafloor must be at least 10,000 m2.

Because outcrops of bedrock and gravel smaller than 10,000 m2 commonly punctuate generally muddy or sandy areas, it was often necessary to map texturally composite features (Barnhardt et al., 1996 a, b).

On side-scan sonar images, rock, mud, gravel and sand usually produce distinct acoustic returns, and so were mapped as distinct units. Rock yields a strong surface return (dark on side scan sonar records) often with great bathymetric relief and fractures that result in areas with acoustic shadows. Gravel deposits also produce a relatively strong acoustic return (black to dark gray on side scan sonar records), and are often closely associated with rock, but lack relief and fractures and are often covered with ripples or boulders. Sand produces a much weaker acoustic return (light to dark gray on side scan sonar records) than either gravel or rock, and usually lacks local relief. Mud yields a very weak surface return (light gray to white on side scan sonar records) and, except where it accumulates on steep slopes or near gas-escape pockmarks, it is associated with a smooth seabed.

When sand, gravel, rock and mud were greater than 10,000 m2 in area, they were mapped as separate units. In many places, however, a heterogeneous seabed composed of numerous small features required establishment of composite map units (Figure 1). In an area where no single seafloor type exceeded 10,000 m2, a composite unit in which one of the "end members" of sand, mud, rock and gravel was dominant and another subordinate was defined. Further subdivision on the relative abundance of one or another bottom types was not possible.

Seismic Reflection Profiles

A limited number of seismic reflection profiles were gathered earlier (Kelley and Belknap, 1989)(Kelley et al., 1997a). A Raytheon RTT 1000a 3.5/7.0 kHz unit with a 200 kHz fathometer trace was used mainly in relatively shallow water over muddy bottoms, while an ORE Geopulse "boomer" seismic system was most effective in deeper water over thicker deposits of sandy or gravelly sediment.

Although seismic reflection profiles are most useful in constructing the geological history of an area, the bathymetry and geological context provided by the seismic reflection profiles, along with the strength of the surface return, also allows identification of the surficial deposit. When used in conjunction with the side scan sonar, both the age and nature of the surficial sediment are easily interpreted (Barnhardt et al., 1996a, b).

Navigation and Compilation

Navigation fixes were made every 2-5 minutes with a differentially corrected global positioning satellite system that annotated directly on the side scan sonar records when an "event mark" was made (Figure 1). The accuracy based on these observations varied from less than +/- 10 m. The earlier seismic reflection and bottom sample work relied on LORAN for navigation with an accuracy of +/- 100 m.

All navigation was converted to Universal Transverse Mercator projection (UTM) and plotted through the geographic information system (GIS), ARC/INFO (UNIX version 7.03). The shoreline of the region was digitized from National Ocean Survey Charts of Penobscot Bay. Bathymetry was digitized at a 10 m contour interval from NOAA Bathymetric and Fishing Charts. The charts are only provisional blue-line paper copies, but they provide a 2 m contour

interval in many locations. Difficulty in interpretation of positive and negative changes in bathymetry on the poorly labeled charts created many possible errors especially in areas where we lacked accompanying geophysical data. <u>Partly for this reason we caution users of the maps that they are not suited for navigation purposes</u>.

The surficial maps (Kelley et al., 1997b) were prepared by overlying the side scan sonar navigation fixes on the bathymetry in the GIS. A buffer, or area equal to the observational range of the side scan sonar instrument, was drawn parallel to the navigation fixes, and the surficial geology was interpreted from the original side scan sonar records onto a mylar cover sheet that was itself later digitized. Where the spacing of the side scan sonar lines was less than the width of the range, the surficial geology between the lines was interpolated with the aid of the bathymetry, bottom samples and seismic reflection profiles (where they existed). These interpreted swath lines are depicted in bright colors. Each color represents one of the end members (mud, gravel, sand, rock). Patterns over the colors relate to the specific composite map unit that was observed. Where side scan sonar data were scarce or absent, reliance was placed on seismic reflection records and bottom samples in conjunction with bathymetry. These data are depicted in dull colors on the atlas maps and lack patterns since detailed textural information could only be discerned from the side scan sonar data (Barnhardt et al., 1996a, b).

Physiographic maps (Kelley et al., 1997c) were prepared largely on the basis of the bathymetry with supplementary information provided from the geophysical data (Kelley and Belknap, 1989).

Feature maps (Kelley et al., 1997d) were compiled from standard NOAA charts for buoys, cable crossings, disposal sites and LORAN coordinates in Penobscot Bay. These were earlier compiled in Barnhardt et al., 1996a, b).

Source and Characteristics of the Data Used

Bathymetry was digitized at a 10 m contour interval from NOAA, National Ocean Service Topographic/Bathymetric Bathymetric, Fishing Maps #68, 69, 70, 71 (all provisional).

Earlier bottom samples and geophysical data were drawn from Kelley and Belknap, 1989, Barnhardt et al., 1996a, b; Kelley et al., 1994).

Features and LORAN were digitized from NOAA charts 13309, 13305, 13303, and 13302.

Side scan sonar data were gathered as described above, along lines of the metadata submitted to the Maine Office of Geographic Information Systems.

Metadata

Metadata forms have been submitted through email to the Maine Office of Geographic Information Systems.

References Cited

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996a, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Boothbay Harbor to

North Haven. Maine Geological Survey Geologic Map 96-9, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996b, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Rockland to Bar Harbor. Maine Geological Survey Geologic Map 96-10, 1:100,000.

Folk, R. L., 1974, Petrology of Sedimentary Rocks: Austin, Texas, Hemphill Publ. Co. , 182 p.

Kelley, J.T., and Belknap, D.F., 1989, Geomorphology and sedimentary framework of Penobscot Bay abd adjacent inner continental shelf. Maine Geological Survey Open-File report 89-3, 35 p.

Kelley, J. T., Belknap, D. F., Dickson, S. D., Barnhardt, W. A., and Henderson, M., 1994, Giant seabed pockmarks: Evidence for gas escape from Belfast Bay, Maine: Geology, v. 22, p. 59-62.

Kelley, A.R., Kelley, J.T., and Dickson, S.M., 1997a, Geophysical data map for Penobscot Bay. Contract map for the Island Institute, 1:100,000.

Kelley, A.R., Kelley, J.T., and Dickson, S.M., 1997b, Surficial geology map for Penobscot Bay. Contract map for the Island Institute, 1:100,000.

Kelley, A.R., Kelley, J.T., and Dickson, S.M., 1997c, Physiographic map for Penobscot Bay. Contract map for the Island Institute, 1:100,000.

Kelley, A.R., Kelley, J.T., and Dickson, S.M., 1997d, Feature map for Penobscot Bay. Contract map for the Island Institute, 1:100,000.